Route Optimization for Energy Efficient Airport Shuttle Operations – A Case Study from Dallas Fort Worth International Airport

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OVERVIEW

Context
- Dallas Fort Worth International Airport (DFW) operates approximately 300 shuttle buses across various service operations. 56 of these serve the rental car center moving passengers between terminals.
- The rental car shuttle fleet consumes 653,817 gasoline gallons equivalent (GGE) of fuel per year and generates 5,700 tons of CO2 each year.

Goals
- Use optimization modeling combined with discrete event simulation to solve the 'travel within the airport premises' shuttle route optimization problem with respect to the rental car center.
- Explore tradeoffs between passenger wait times and the energy efficiency of transporting passengers between the rental car center and the terminals at DFW.

METHODOLOGY

Optimization Model
- Mixed Integer Linear Program (MILP)
- Solves the dispatching problem to minimize hourly energy consumption by the bus fleet.
- Provides a set of shuttle routes.
- Determines the number of buses serving each route.

Discrete-event Simulator
- Tests the performance of the routing solution provided by the optimization model in a stochastic environment.
- Uses stochastic dwell times, travel times, and arrival rates.

Controller Area Network (CAN) Bus Data
- DFW allowed NREL researchers to collect CAN bus data from the rental airport shuttles using vehicle data loggers resulting in approximately 100,000 miles of 1Hz data from 14 buses over a period of one month of operation.

Context
- Virtual Conference
- Information contained in this poster is subject to a government license.

DATA

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RESULTS

Baseline Simulation Statistics
- In the first example routes were used in in-vehicle travel time and bus headways were chosen to be very stringent. We see the optimal routes are the most direct routes between terminals and the rental car center. Additionally, we see high numbers of buses on each route throughout the day. Finally, we see the distribution of passenger waiting times is very close to the baseline case. We note that in the case the average waiting time for a bus is 4.6 minutes and on average uses 51% more GGEs than our baseline simulation.

In the second example before the max in-vehicle travel time and bus headways were less stringent. As a result, two buses were used on the routes throughout the day, and the optimal routes visited multiple terminals before returning the rental car center. The histogram of passenger waiting times has a larger tail than the baseline case, and the average waiting time for a bus is 4.8 minutes. These routes use 50% less GGEs on average per week than our baseline simulation.

INSIGHTS GAINED
- Simulation of routes in a stochastic environment proved to be a useful way to understand the trade-offs between energy consumption and passenger wait times.
- Reducing fuel energy consumption, and passenger wait time are competing objectives, where a trade-off frontier is present.
- Route combinations exist where average weekly energy consumption is reduced by 20-25% while average weekly passenger wait time is increased by 10-15 minutes.
- Routes with lower average energy consumption also have lower average passenger wait times. The average passenger wait time in the second case was reduced by 5-7 minutes.